



Case 3 Results Verification Exercise

compiled by the HiLiftPW Committee

Overview

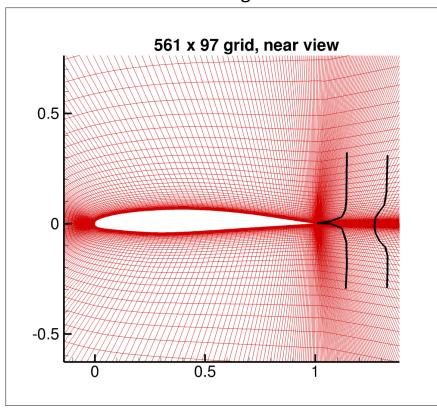


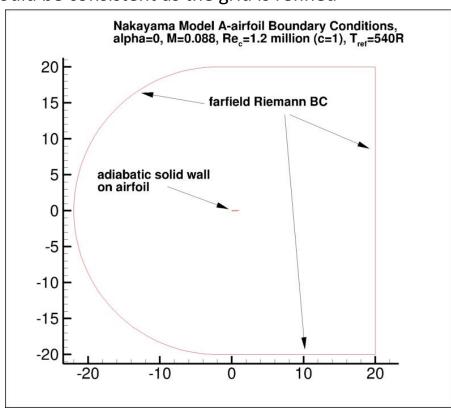
- Sources of differences between CFD results (assuming use of the correct geometry):
 - Different equations
 - This may be a due to unintentional bugs in the software
 - Or it may be on purpose (e.g., tweak to a turbulence model)
 - Use of different boundary conditions
 - Insufficient grid refinement
 - VERIFICATION can help diagnose this
 - Strong verification: method of manufactured solutions (MMS)
 - Weak verification: Turbulence Model Resource (TMR) website (https://turbmodels.larc.nasa.gov)
- We will show you: many of the codes used in this workshop have not been verified
- We will attempt to link inconsistencies in the verification case to inconsistencies in the large high-lift cases

Case 3 – 2D Airfoil Near-Wake Verification



- Study a simple 2-D case of near-wake behind DSMA661(MODEL A) airfoil (J. Fluid Mech. (1985), Vol. 160, pp. 155-179) from TMR website
- Compare CFD results that <u>use ostensibly the same turbulence model</u> to each other
 - For SA and SST, consistent results from 2 codes are taken from the TMR website
 - Results for a given turbulence model should be consistent as the grid is refined



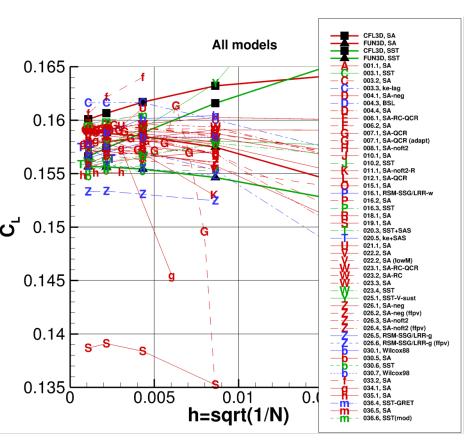


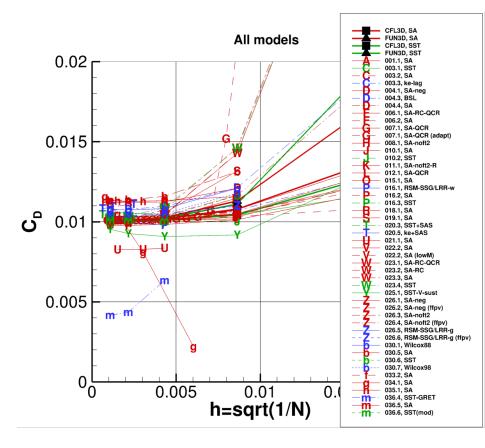
Note possible issue: farfield BC extent of only 20c means that solution differences may occur because of non-identical farfield BC implementations

Overall results for Case 3



Lift and Drag





Red: SA-type models

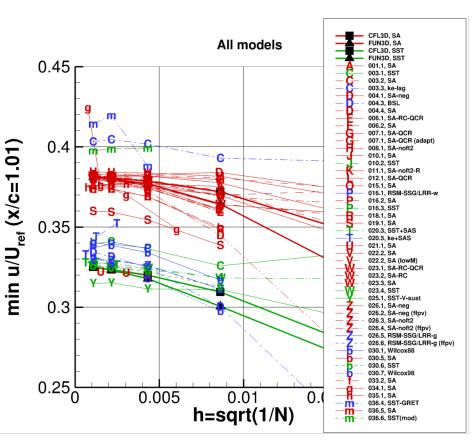
Green: SST-type models

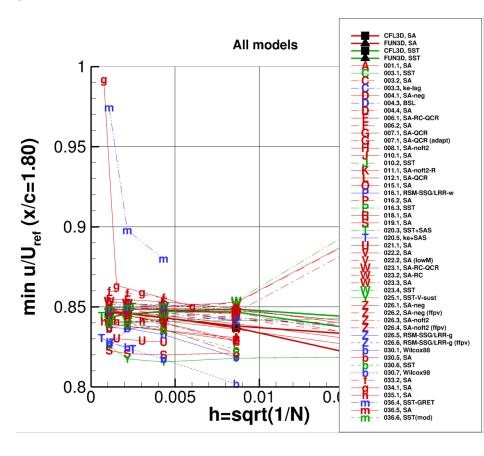
Blue: Other models

Overall results for Case 3



Min u-velocity in the wake





Red: SA-type models

Green: SST-type models

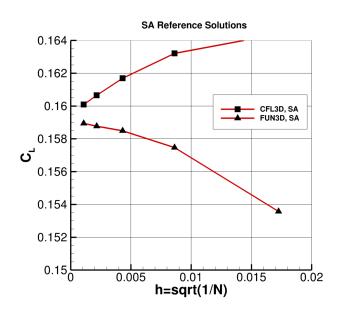
Blue: Other models

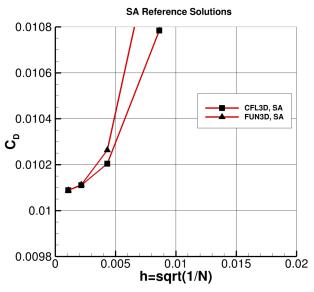


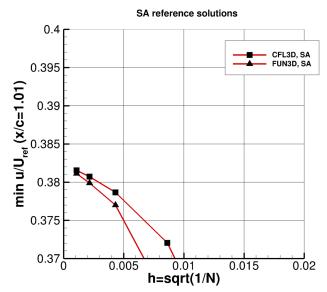
SA model

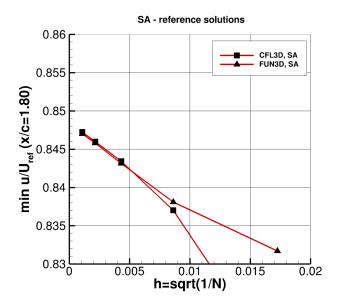
SA – reference solutions





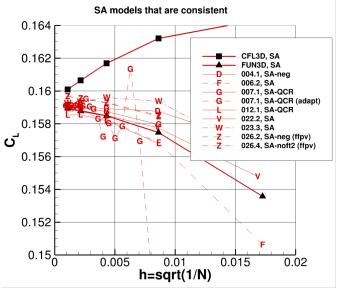


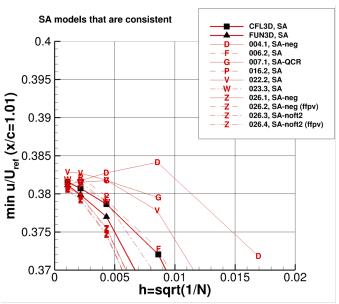


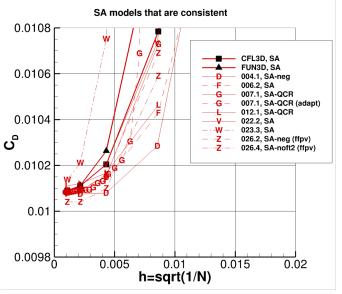


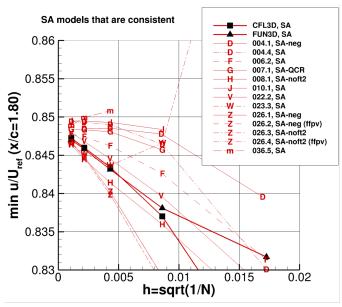
Identify SA results that are consistent











PID	Plot letter	CL	CD	Velmin 1.01	Velmin 1.80	Overall
001.1	Α	No	No	No	No	No
003.2	С	Υ	Υ	close	No	No
004.1	D	Υ	Υ	Υ	Υ	Υ
004.4	D	close	Υ	close	Υ	close
006.2	F	Υ	Υ	Υ	Υ	Υ
007.1	G	Υ	Υ	Υ	Υ	Υ
008.1	Н	Υ	close	close	Υ	close
010.1	J	close	Υ	No	Υ	No
012.1	L	Υ	Υ	(missing)	(missing)	Υ
015.1	0	close	close	(missing)	(missing)	close
016.2	Р	close	close	Υ	No	No
018.1	R	No	No	No	No	No
019.1	S	No	No	No	No	No
021.1	U	Υ	No	No	No	No
022.2	V	Υ	Υ	Υ	Υ	Υ
023.3	W	Υ	Υ	Υ	Υ	Υ
026.1 & 3	Z	close	Υ	Υ	Υ	close
026.2 & 4	Z	Υ	Υ	Υ	Υ	Υ
030.5	b	No	No	No	No	No
033.2	f	Υ	No	No	No	No
034.1	g	close	No	No	No	No
035.1	h	No	No	No	No	No
036.5 AIAA HILII	ftpw-3 - Denver, CO,	USA June 3-4, 2017	Υ	No	Υ	No ⁹

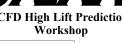
Overall summary for the SA model

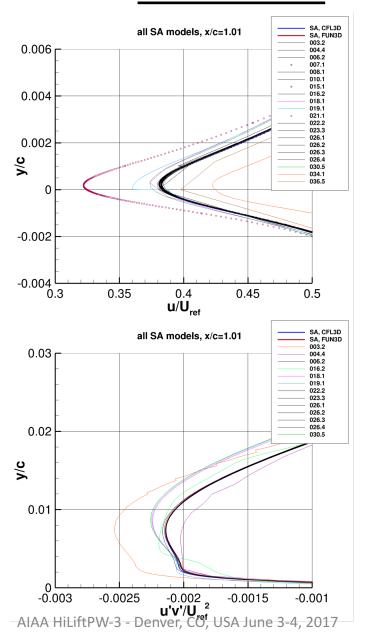


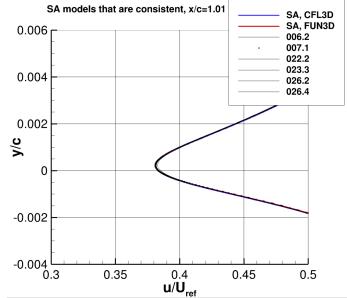
- SA results include SA, SA-neg, SA-noft2, and SA-QCR
 - Not including R or RC variants here
- Consistent with each other:
 - CFL3D, FUN3D, 004.1, 006.2, 007.1, 012.1, 022.2, 023.3, 026.2/4 ... 30% of entries
- Fairly "close", but not fully consistent:
 - **004.4, 008.1, 015.1, 026.1/3**
- Not-so-close:
 - 001.1, 003.2, 010.1, 016.2, 018.1, 019.1, 021.1, 030.5, 033.2, 034.1, 035.1, 036.5
 - Note: 036.5 was consistent on 3 out of 4 measures

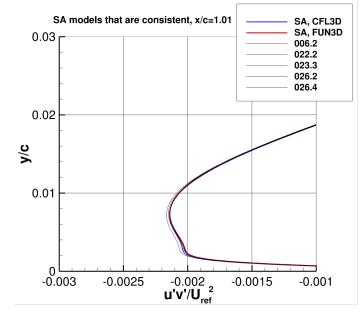
Look at consistent SA results in wake













Cross-correlation with High Lift Cases

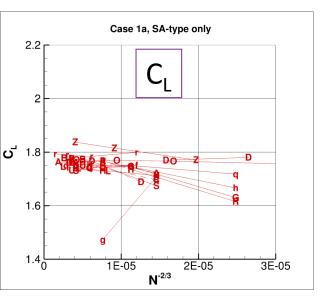
SA only (there were not enough results from other models to draw conclusions)

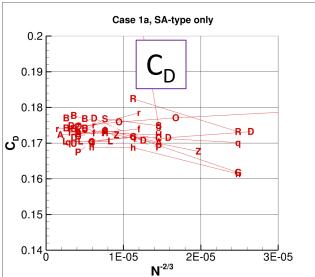
Note: some ran Case 3 but did not run high lift cases with the same model (only plotting those who did)

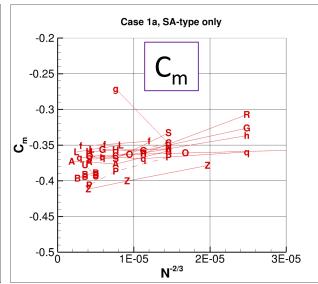
HL-CRM, alpha=8 deg.







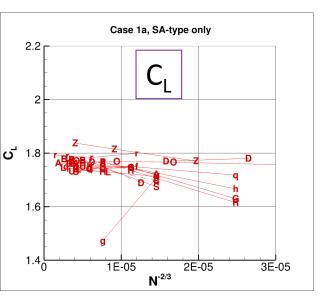


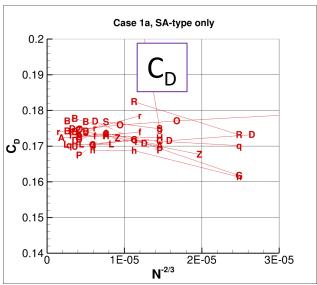


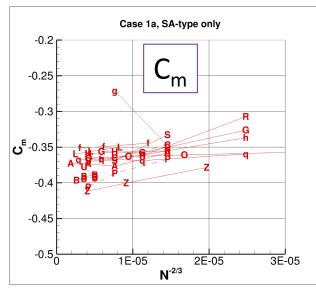
HL-CRM, alpha=8 deg.

All SA Results

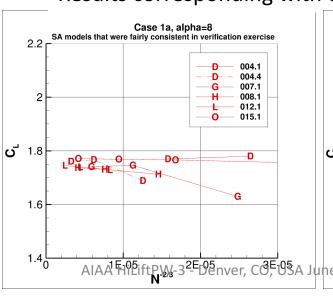


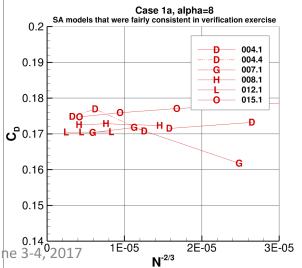


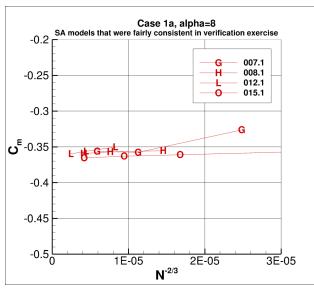




Results corresponding with the most consistent SA solns from Case 3



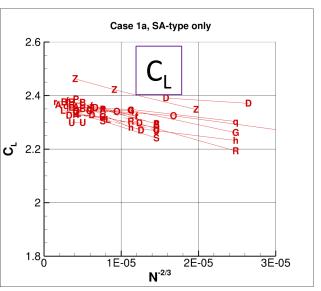


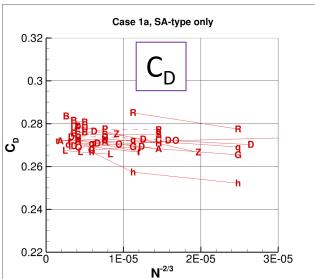


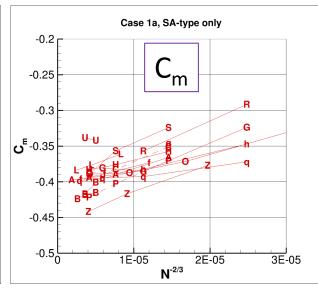
HL-CRM, alpha=16 deg.







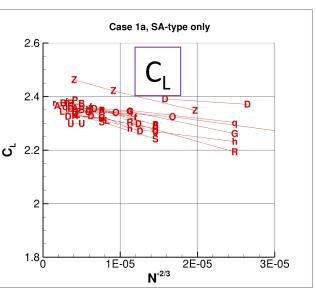


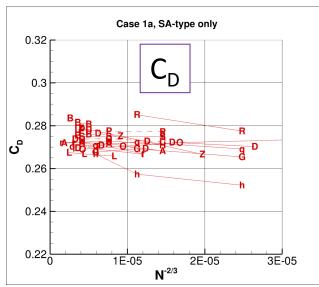


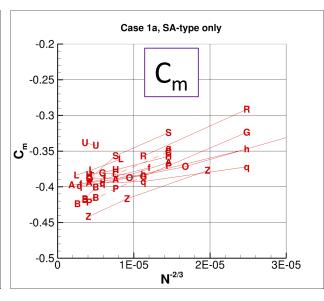
HL-CRM, alpha=16 deg.

All SA Results

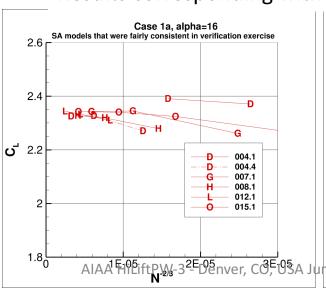


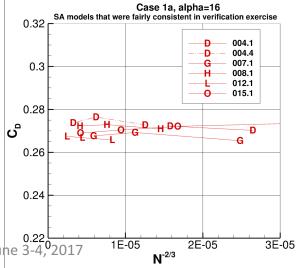


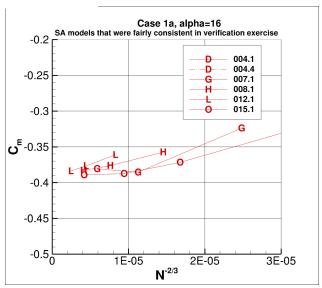




Results corresponding with the most consistent SA solns from Case 3



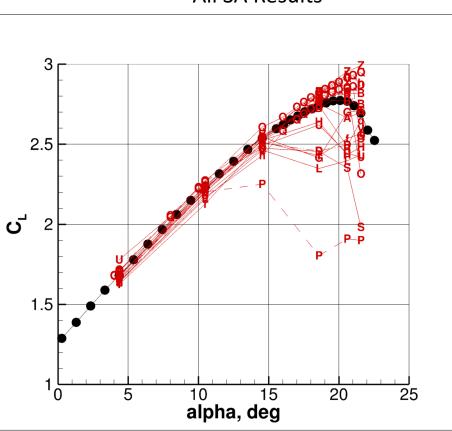




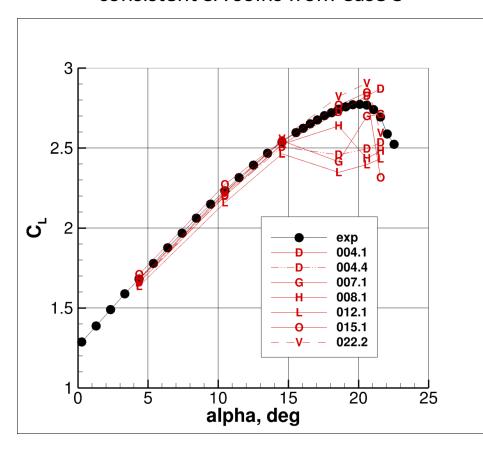
JSM, no nacelle/pylon



All SA Results



Results corresponding with the most consistent SA solns from Case 3



No consistency near $C_{L,max}$

Other models



- SST results
 - Had far less contributions
 - Could <u>not</u> note trends with high-lift cases
 - Three results were consistent with CFL3D & FUN3D case 3 reference solution:
 - 010.2, 016.3, 023.4
 - Others (003.1, 020.3, 025.1, 030.6, 036.6) were close, but less consistent
 - Note: 020.3 used SST+SAS, 025.1 used SST-V-sust, 036.6 used SST(mod)
- SSG/LRR-RSM-w2012
 - Two contributors (only one ran high lift cases)
 - 026.6 was reasonably consistent with CFL3D (026.5 was off on C₁)
 - 016.1 was not consistent for u_{min} at x/c=1.8

Conclusions



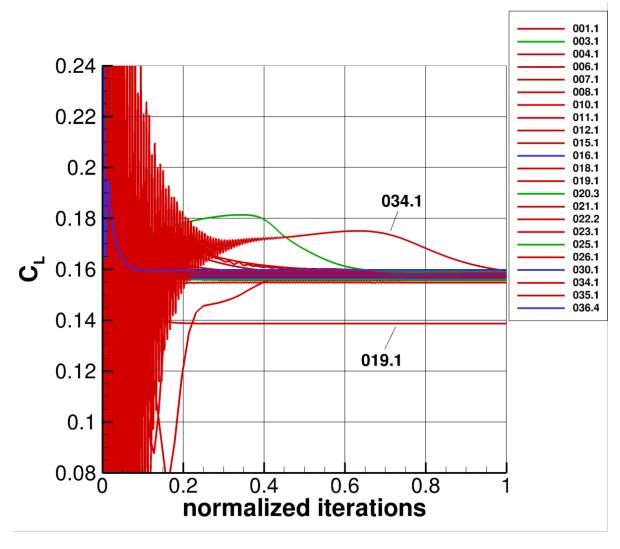
- Similar to previous verification exercises from past DPWs and HiLiftPWs:
 - If a code has not been verified, then you cannot expect to get consistent solutions with other codes
- Only 30% of participants who ran Case 3 with SA were fully consistent
- Taking the PIDs that produced the most consistent Case 3 results (with SA):
 - Their SA results also were generally more consistent for the two HL-CRM cases
 - But they were not consistent for JSM near C_{L,max}
 - no grid study



Backup slides

Sample iterative convergence results for Case 3



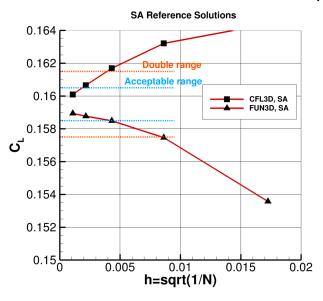


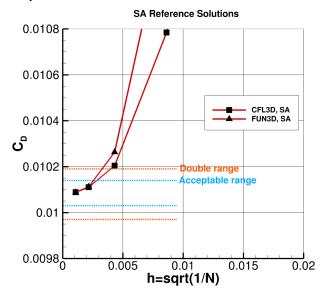
(on fine grid)

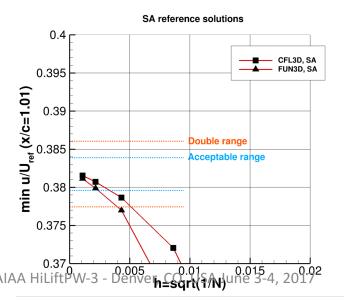
Define a "band of acceptability"

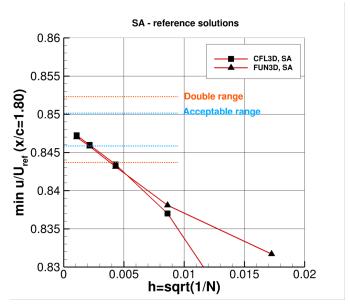


(as h -> 0)









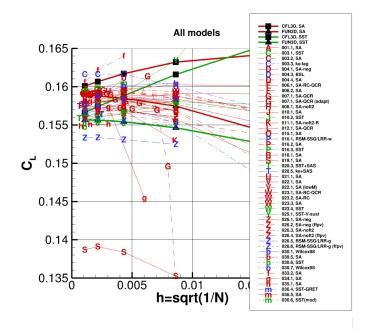
Focus on SA (C_1)

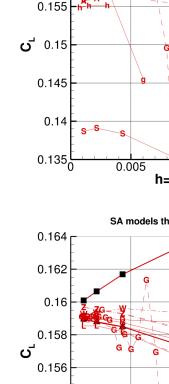


CFL3D, SA
FINAD, SA
O01.1, SA
O01.1, SA
O01.1, SA
O02.1, SA
O02.2, SA
O02.2, SA
O02.2, SA
O02.3, SA
O02.3, SA
O03.2, SA
O03.2,

- 026.3, SA-noft2 026.4, SA-noft2 (ffpv) 030.5, SA 033.2, SA - 034.1, SA - 035.1, SA

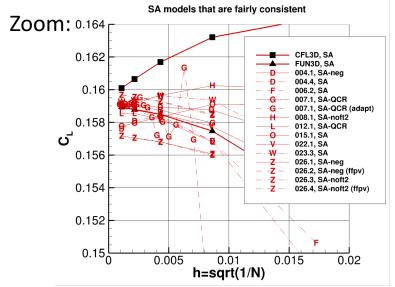
0.02

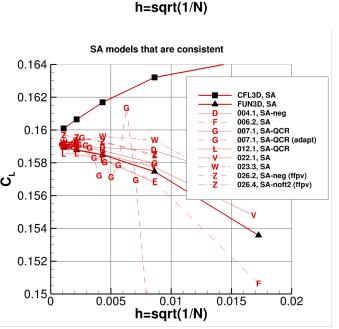




0.165

0.16





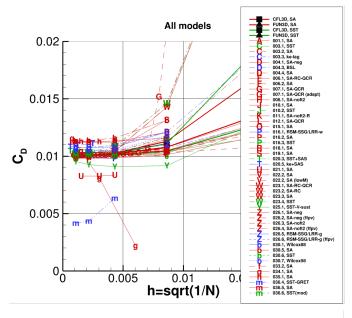
0.01

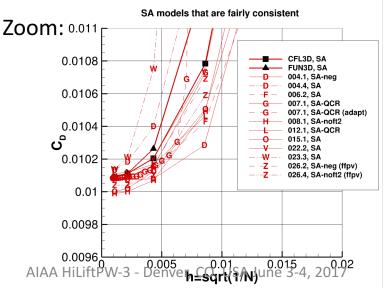
0.015

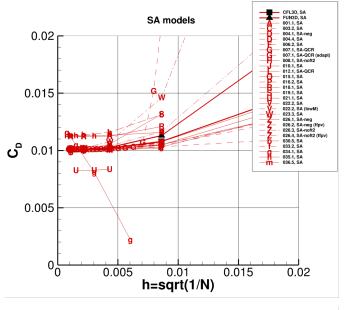
SA models

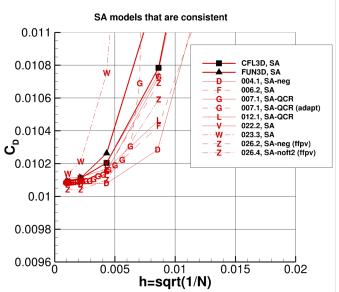
Focus on SA (C_D)





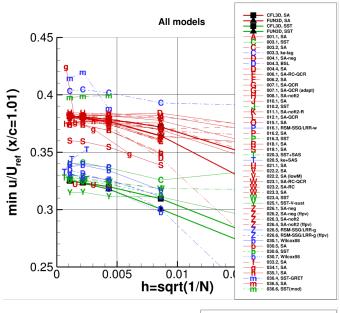


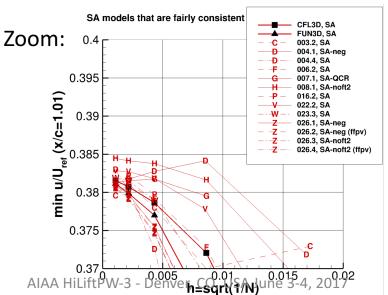


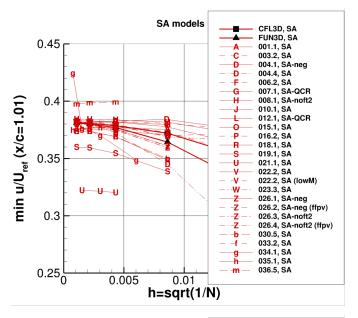


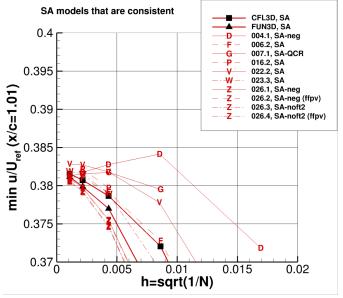
Focus on SA (u_{min} at x/c=1.01)





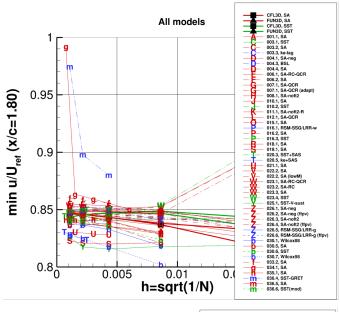


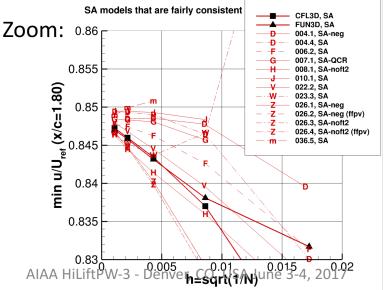


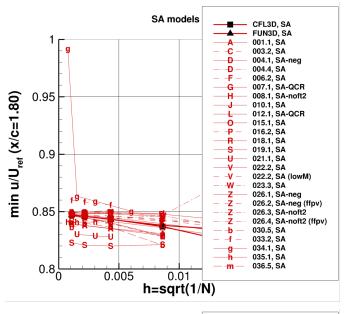


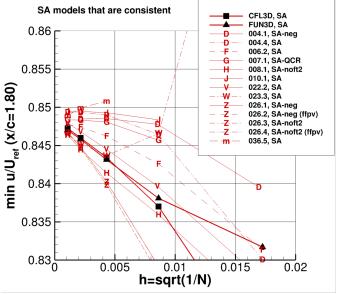
Focus on SA (u_{min} at x/c=1.80)



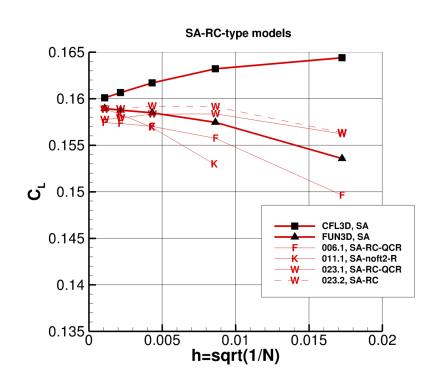


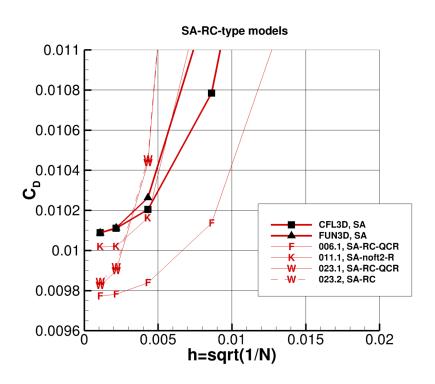






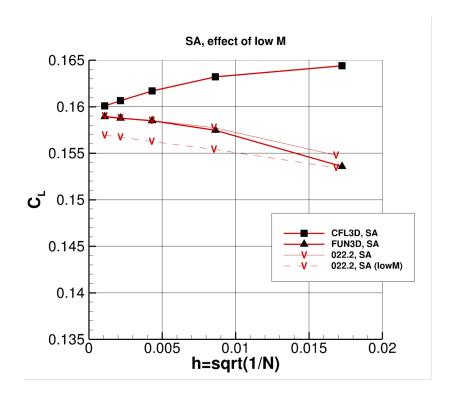


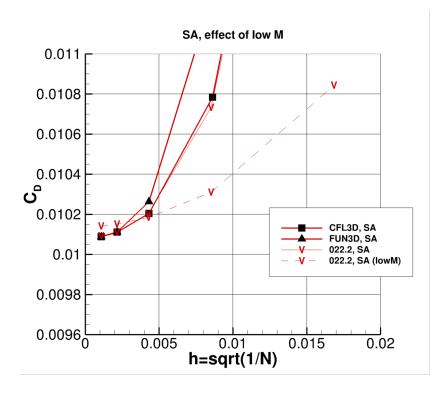




• R or RC appears to lower C_L and C_D somewhat (compared to SA), but there is not enough consistency from the results to know for sure

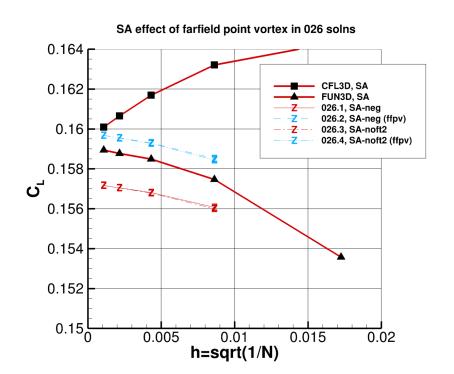


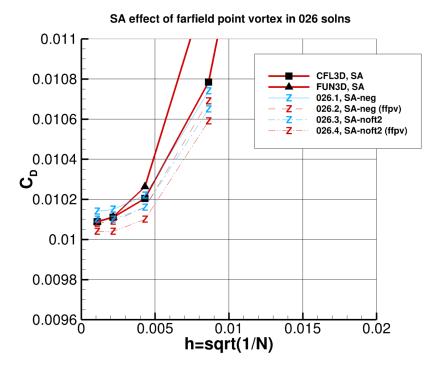




Use of low M preconditioning changes results

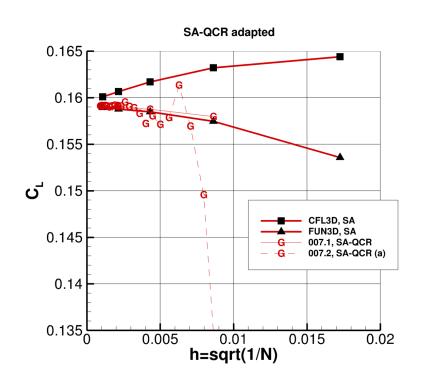


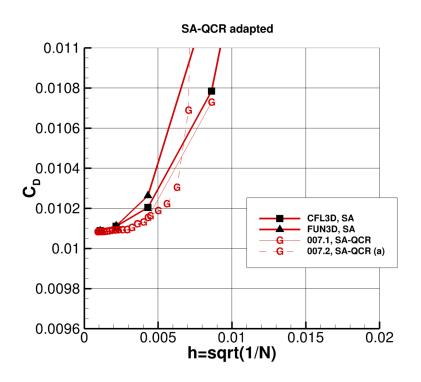




- In 026, a Farfield Point Vortex (ffpv) was required to bring C_L in line with "accepted" solutions
 - Reason for this is not known
 - The reference solutions did not use ffpv
- The noft2 option had a small effect on drag (reason unknown)



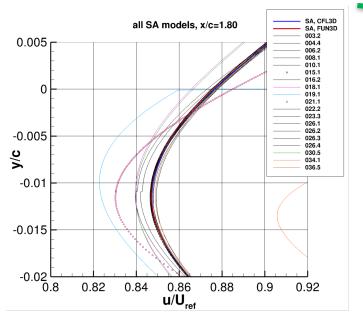


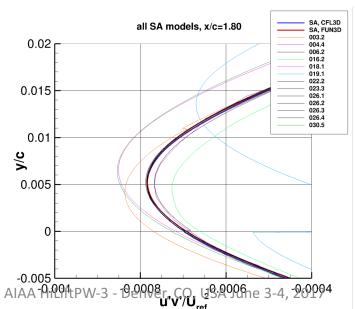


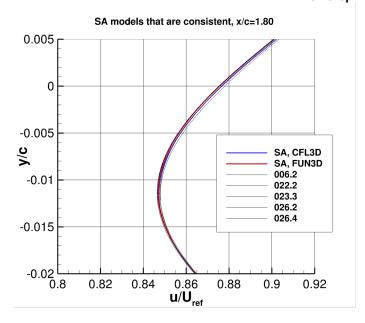
Adapting goes to same result as standard grid refinement

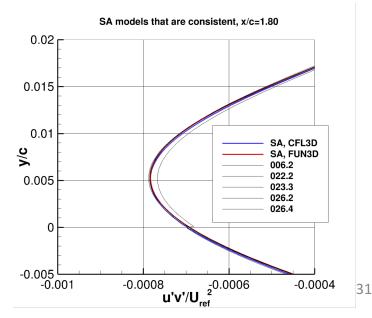
Look at consistent SA results in wake





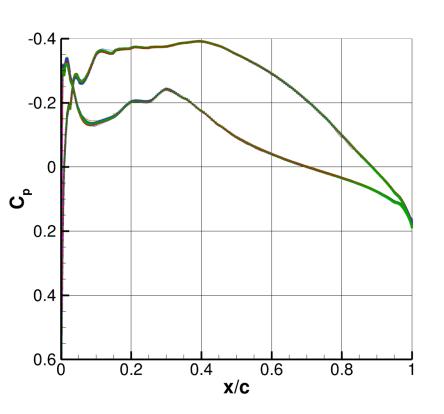


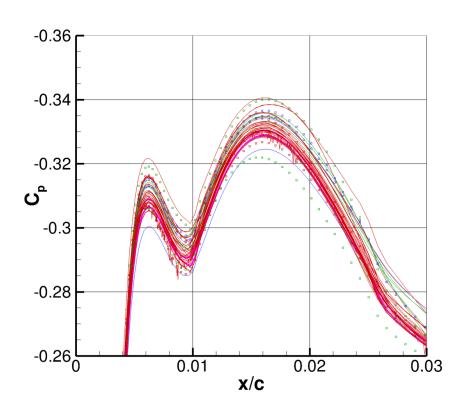




Surface Cp results for Case 3



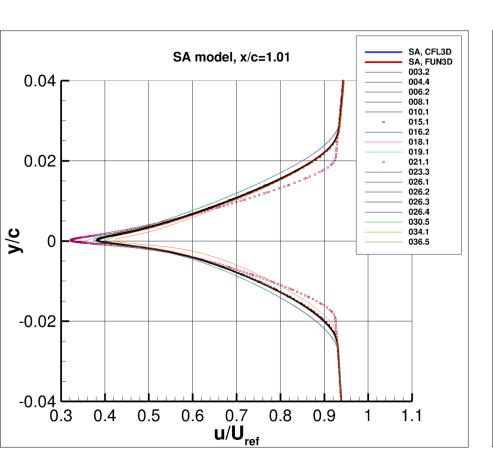


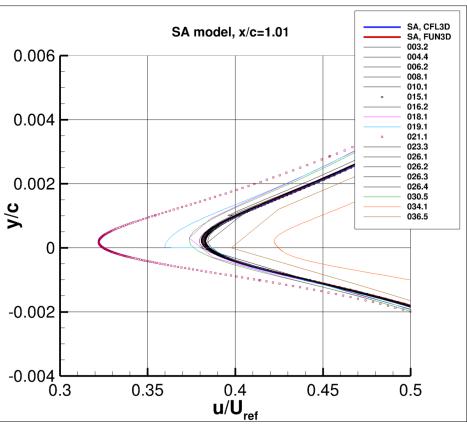


Surface pressure coefficients do not tell us too much

Velocity profiles

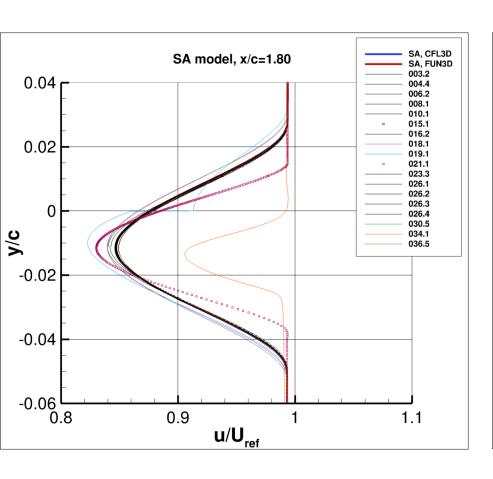


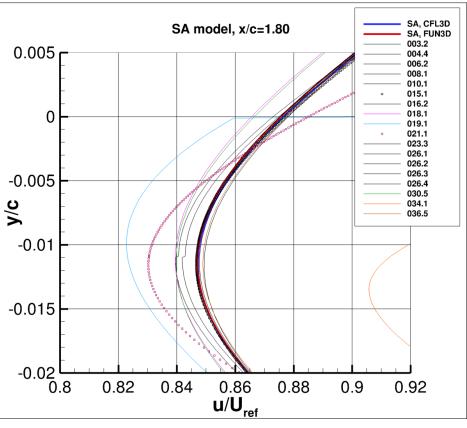




Velocity profiles

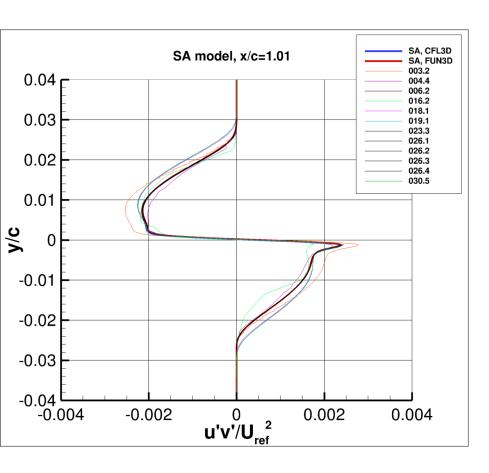


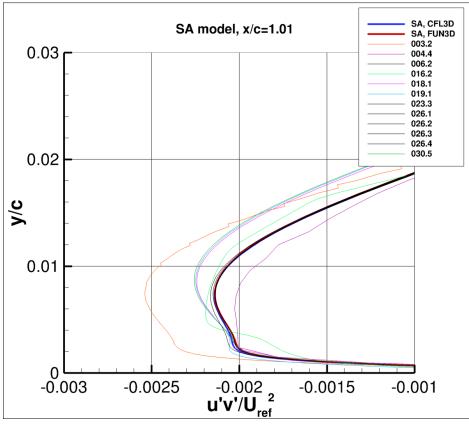




Turbulent shear stress profiles

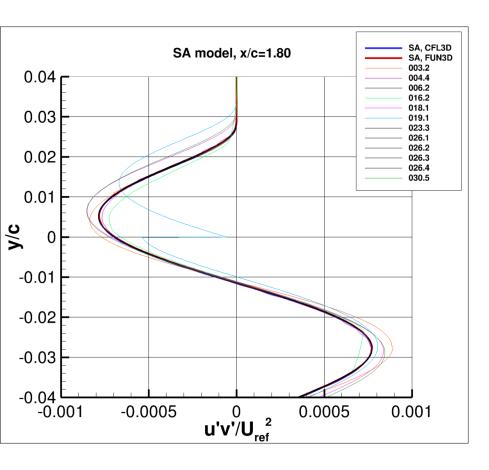


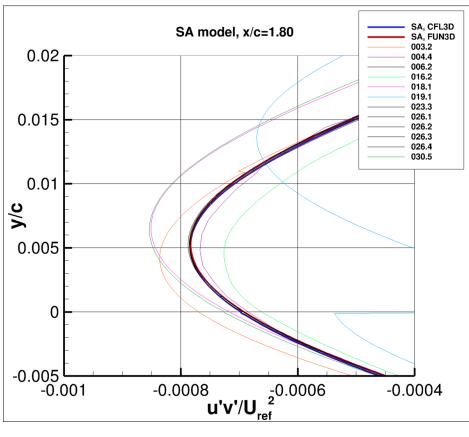




Turbulent shear stress profiles





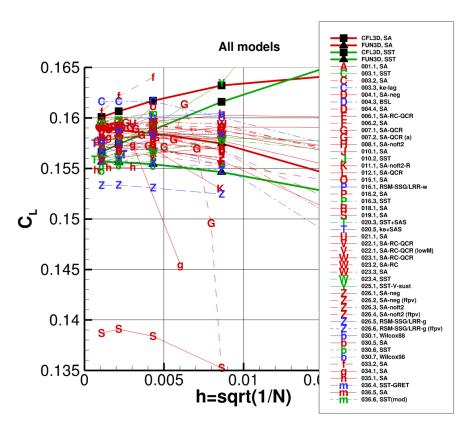


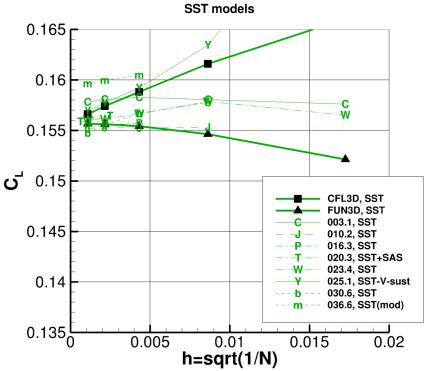


SST model

Focus on SST (C₁)

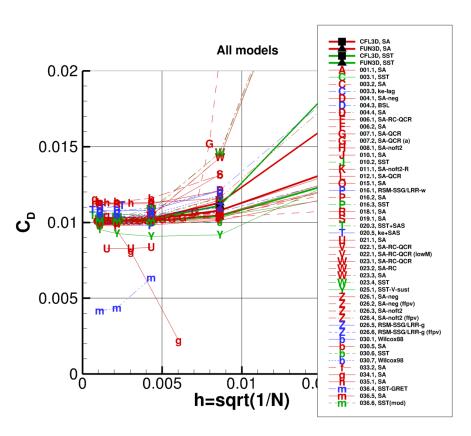


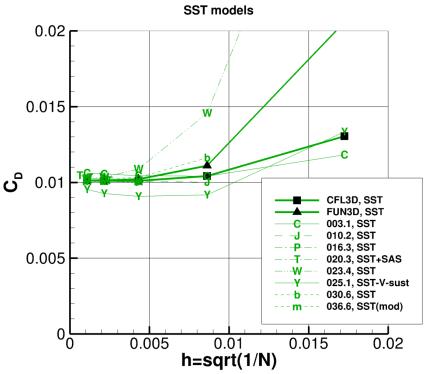




Focus on SST (C_D)

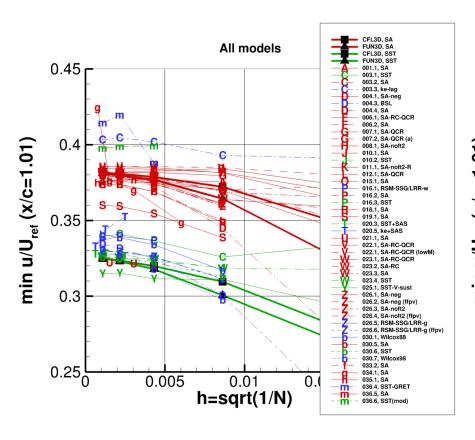


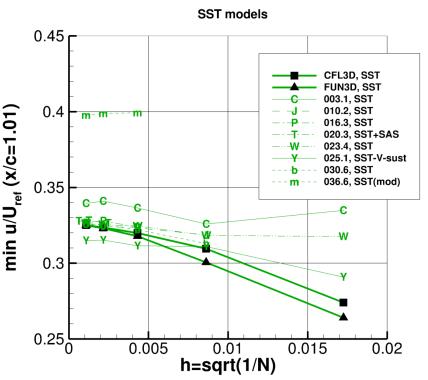




Focus on SST (u_{min} at x/c=1.01)

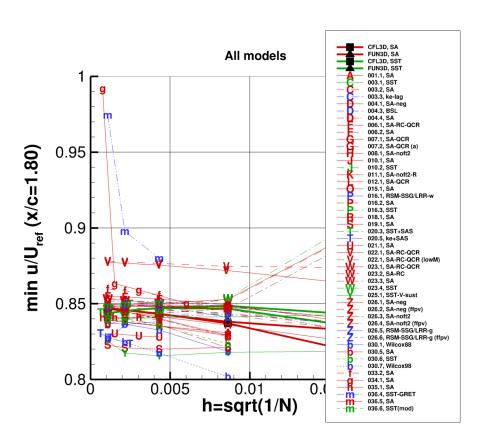


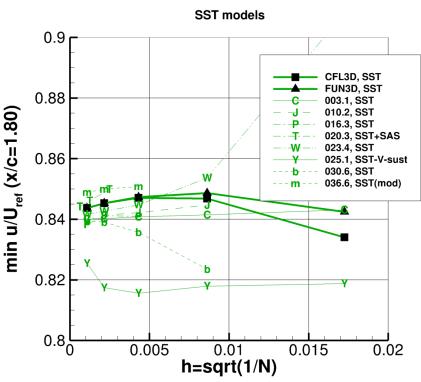




Focus on SST (u_{min} at x/c=1.80)



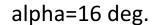


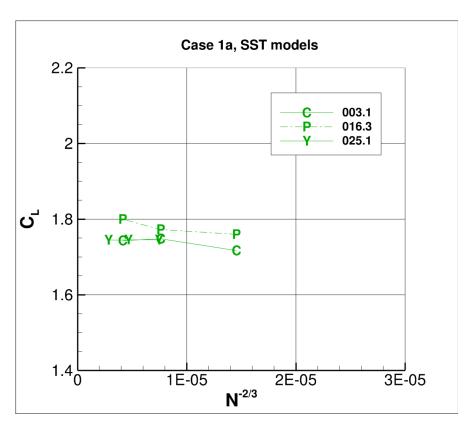


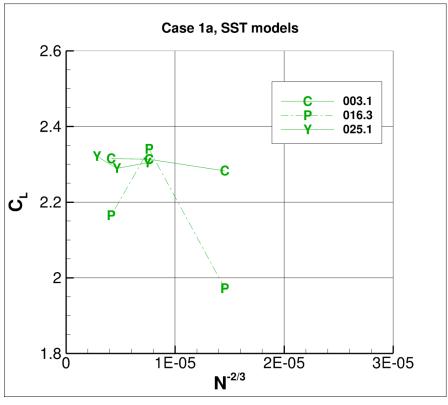
SST models from case 1a



alpha=8 deg.





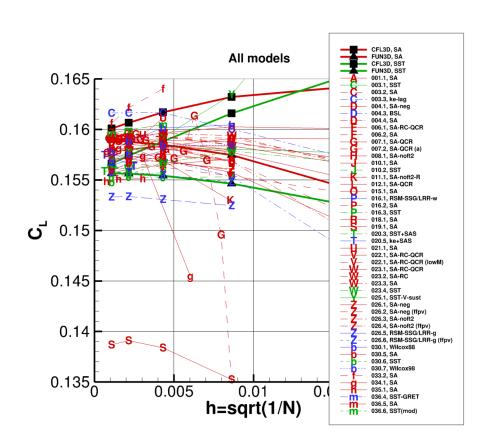


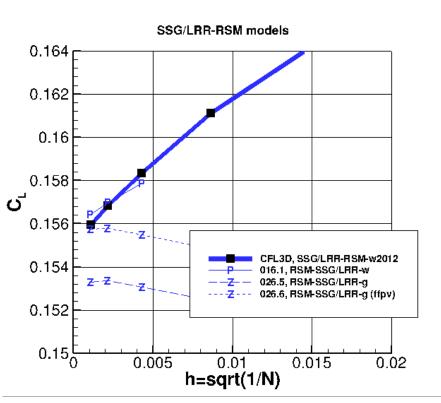


SSG/LRR-RSM model

Focus on RSM (C_1)



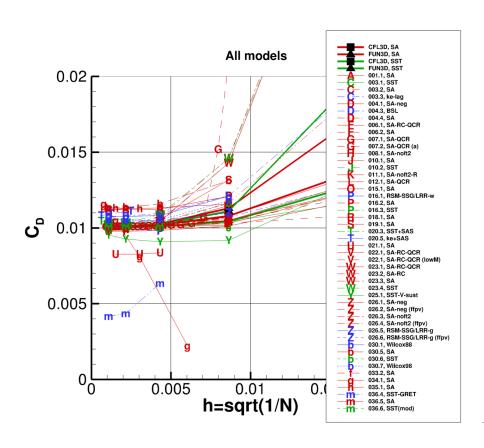


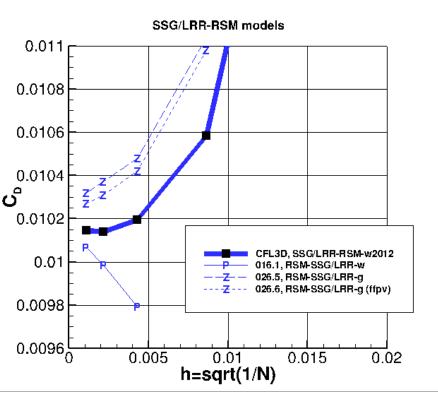


CFL3D was run for comparison to the 2 submitted results

Focus on RSM (C_D)

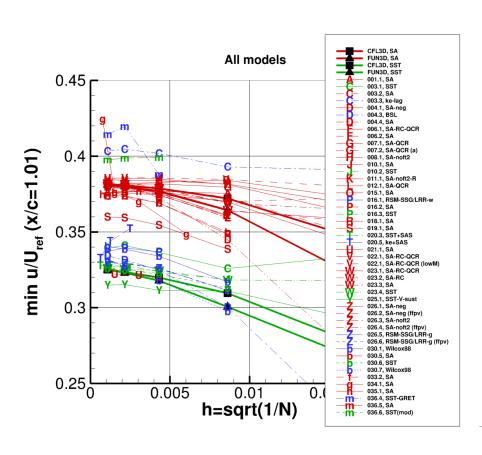


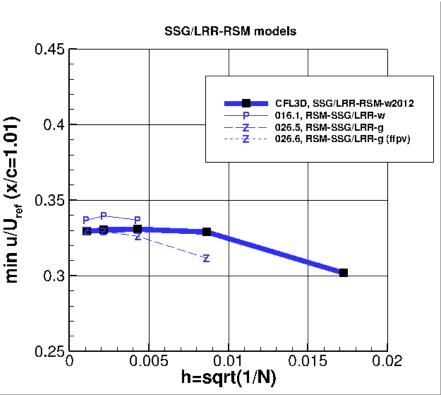




Focus on RSM (u_{min} at x/c=1.01)







Focus on RSM (u_{min} at x/c=1.80)



